University of Maine.

Maine Agricultural Experiment Station

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STUDIES OF LIFE HISTORIES OF FROG-HOPPERS OF MAINE

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dition. This condition persists even during rather heavy rains, showing a certain insolubility in water as well as in alcohol. The glands from which the secretion comes are located laterally in the abdominal segments (the 7th and 8th) and in a specimen of one of the intermediate instars, probably the third, they appear as black spots. In other instars, so far as observed, they are not specially colored but show in mounted specimens as a more opaque area while the surface is roughened over a triangular area though no gland openings have been observed in the material studied. The pores may be too minute for ready observation. A similar secretion has been observed for *Clastoptera.*

The purpose of the frothy masses is generally assumed to be for the protection of the nymph and it is easy to see that they are pretty well guarded against many of the smaller kinds of enemies such as spiders and other arthropods. Some distinct adaptations associated with the habit are to be noted as for instance, the loss in large degree by the nymphs of the leaping habit and also the nearly complete loss of color.

That these two species have a distinct preference, if not a positive restriction to particular food plants is indicated by the fact that *spumarius* is taken almost entirely from plants other than grasses while *lineatus* is taken almost exclusively from grasses, especially timothy and redtop.

As a test of their choice in this matter on July 9th ten individuals of *lineatus* were transferred from timothy to clover and of these none lived, though two had succeeded in changing to adult stage probably being very near maturity. In the reverse test ten specimens of *spumarius* were transferred from clover to timothy and only two lived to become adults, none made froth on the timothy and all showed restlessness and attempts to move. They evidently failed to secure sap and it is possible that there is some distinct difference in the mouth parts correlated with the different food plants as well as a difference in selection.

The economic importance of these species has been variously estimated though I think too generally overlooked. I find in an early record in the *Maine Farmer* for July 26, 1866, the following note by G. E. Brackett under the head of "Practical Entomology:"

"About 'Hoppers.' There is a class of insects including three families, the leafhopper, treehopper and froghopper, which present some peculiar characteristics, the species most common here is the froghopper (Cercopida) so called. Every farmer will have noticed upon plants, particularly on grass, a mass of foam or spittle-like substance, adhering to the stalk, and containing an insect, which, from the fact that it leaps when disturbed, may have been called a young grasshopper. This is the froghopper, of the order Homoptera, and entirely distinct from the grasshopper, in having a tube to suck juices instead of jaws to bite leaves, as do grasshoppers and all other orthopterous insects. These froghoppers hatch from eggs laid in the previous autumn, and immediately puncture the tender bark of the plant with their beak and suck out the sap. They take in such large quantities that it oozes out of their bodies in the form of minute bubbles which soon form a covering of foam or spittle-like substance, which gives it its name. This substance shelters it from the sun and also from insect enemies. When they become full grown in autumn they are not thus protected, but are found moving about on the plants where they lay their eggs. A description of this insect will be unnecessary, as every reader has seen them. There is general resemblance among the different families of hoppers. They are not considered particularly destructive to the plants on which they are found."

In speaking of the injuries of the spittle insects Dr. Lintner (Fifth Report on the Injurious and Other Insects of the State of New York, p. 246, 1889) remarks as follows:

"Report has been made in Vermont of one or more of the grass infesting species causing considerable damage to the hay crop. It was estimated that in consequence of the depredations, the quantity of hay grown on some fields was one-third less than the natural yield, not including the depreciation in the quality of the crop. It is but seldom however, that these insects increase to such an unusual extent as to become of serious injury, and it is therefore unnecessary to indicate any means for their destruction. A gentleman, who asks for information regarding them, states that, in passing through his mowing fields, in Auburn, Mass., they are so numerous as to wet his shoes. An abundance such as this would of course, be harmful to the crop but, fortunately it is of rare occurrence."

Occurrences such as these are perhaps less rare than is generally supposed since these insects are easily overlooked and the tendency has been to give little heed to the attacks of insects unless they are severe enough to cause a very complete destruction of a crop. I am informed by Dr. Patch that occurrences where the insects are abundant enough to wet ones shoes in walking through grass are not infrequent and in my collecting the present season I have found them plentiful enough for this

purpose and often plentiful enough so that my net would become wet while sweeping the grass for specimens. As shown elsewhere by actual counts and estimates the drain on certain fields is such that it well deserves attention and the determination of measures for control.

If old fields showed uniformly small plants there would be some reason to attribute the reduction in growth to the soil or to "running out" but when scattered stems stand at good height and produce excellent heads it seems that this explanation is insufficient.

It is a peculiar sight in some fields to note a considerable number of tall well developed stalks with large heads in full bloom and along with them in exactly the same soil and exposure to sun, rain and other conditions, numerous dwarfed plants with short, blasted heads or no heads at all.

While some mention of the species has been made by these earlier writers there has been scarcely any reference to the species or their possible economic importance by later writers and there is evidently opportunity for some careful observations and experiment to determine their habits and possible measures for control. The observations recorded here it is hoped will furnish a basis for any more detailed studies that may be possible in the future, but they will serve, it is believed an immediate purpose in suggesting some measures which should help in the reduction of the losses from this source.

Meadow Froghopper.

(*Philaenus spumarius* L.)

This extremely abundant species is widely distributed in the eastern United States as well as in Europe. It is probably the species most commonly referred to in mention of froghoppers although the nearly related species *P. lineatus* has been doubtless often the basis of comment. In general works the two species are seldom distinguished but since they have a different food plant range and other differences in habit, a more exact reference seems desirable. In common usage froghopper covers both these and certain other species. To make a more precise distinction I would propose this species be called the

Meadow Froghopper and the *Philaenus lineatus* Grass-feeding Froghopper.

The distribution of the species covers the northern United States west to the plains region at least and in Maine its occurrence may be expected throughout the entire state. In fact it is one of the most abundant species encountered in meadows and pastures and it is found occasionally in cultivated fields of oats.

There is a quite wide range of food plants including many of the compositae as well as several cultivated crops. Among the food plants specially noted were buttercup, yarrow, thistle, helianthus, orange dock, daisy, clover, primrose, chokecherry and plum.

Its economic importance is of course considerably affected by the fact that many of its foodplants are noxious weeds and if it would confine its attacks to such plants it might be counted very useful but since it feeds abundantly on clover its presence in meadows must be counted detrimental.

In life history the species agrees very closely with *P. lineatus* so much so that one statement will almost answer for the two.

Nature of the Injury.

The effects of the attacks of this species are most apparent on the blossoms or the seed formation and in many cases are very evident. This is especially evident in the case of the buttercup which seems to be one of the favorite foodplants. Buttercup heads were marked to indicate those blossoms that were on stems attacked by the hoppers and four marked heads on a plant that bore eight other heads. The four attacked all withered and failed to produce seed while six of the others formed good seed heads and the other two were still in blossom at time the observation closed. See figs. 44 and 45.

Clover blossoms also show the same effect and there is no doubt that the hoppers must be a distinct factor in the reduction of the formation of the perfect clover heads.

Where buttercup is present *spumarius* seems to gather on it in preference to other plants though clover is apparently nearly as much affected.

Life History.

As already indicated the eggs of this species are believed to pass the winter in the meadows where the nymphs are observed in summer and probably they are found in the stems of their various food plants or possibly in dead stems or leaves at the surface of the ground.

The larvæ hatch in early summer, the earliest record which we have for the season of 1916, being June 13. The nymphs were mostly well along at the time of my first field observations in June and I conclude that the rate of growth is rather rapid for the latter part of June as during this time and early July but few less mature than the final instar were to be found. On July 10th these last instar individuals were still plenty on buttercup and a recently emerged adult was observed on dandelion. From the middle of July only adults were observed but these were evidently still feeding and it is certain that mating and egg development are carried along slowly. Mating was observed July 28th, and at this time adults of both sexes were abundant in clover in a meadow. One mated individual, dissected showed no evidence of egg development beyond the most immature formation and no indication of shell. By the middle of August egg development has proceeded so that occasional eggs are found with well formed shells but usually only a few mature eggs along with many imperfect and undeveloped ova in the oviducts. Figure 46 shows this condition as noted in a specimen dissected in August. The large black bodies are the eggs with shells and the faint ones those still unformed. The large spermatheca may also be observed above the ovipositor. No spermatozoa could be detected in the spermatheca but from its size it would seem quite certain that they must be retained for some time and the eggs are fertilized as they mature through a long period possibly several weeks during late summer and early autumn.

No egg deposition was observed before my leaving Maine the last of August and the only eggs seen were those dissected from the females during August.

Description of Early Stages.

Egg: The egg is moderately elongate, irregularly elliptic, about three times as long as broad, narrowing to one end, slightly flattened, one side straight or slightly incurved the other convexly curved, giving the egg a slightly curved appearance. The shell is tough and hard and developed while the eggs are still in the ovariole ducts.

The first instar observed is from two to three millimeters long, the head before the eyes strongly inflated semiglobose or bulbous, polished, with faint arcs on the front. Antennæ short, 8- or 9-jointed, first joint short, 2nd large, 3rd cylindric, 4th to 9th tapering, eyes dark, a distinct transverse furrow or suture across vertex between bases of antennæ. Beak reaching to third pair of legs.

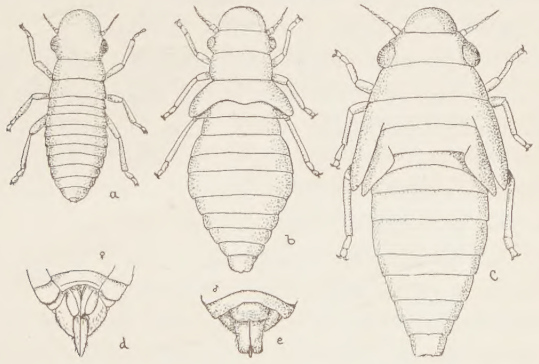

Fig. 38. *Philaenus spumarius, a,* young nymph; *b,* intermediate; *c,* last instar, all enlarged; *d,* female; *e,* male, genitalia. (Original.)

The second instar observed (possibly the 3rd in full series) has the head cordate, front bulbous, a depressed suture from antennal bases, forming a distinct transverse furrow, antennæ 9-jointed; 1st short, 2nd large, short cylindrical, 3rd longest cylindrical, 4th to 9th tapering gradually to tip. Eyes dark brown, reddish on the margins. Prothorax cylindrical; mesothorax expanded at sides to form beginning of wing pads, wider than metathorax slightly produced posteriorly, tips reaching nearly to hind border of the metathorax, hind border slightly curved, metathorax slightly expanded at sides, hind border

nearly straight, transverse; legs not distinctly spined, a few weak points at tip of hind tibiæ. Abdomen widening to 3rd segment, tapering to tip, valves distinct. Length, 4 mm.

In the final instar observed the head is distinctly more pointed though the front is decidedly bulbous, ocelli are evident, the wing pads have developed backward so as to include the first two abdominal segments, those of the mesothorax being appressed to those of the metathorax and reaching almost if not quite to their tips. Head with vertex produced, subangulate, a depressed furrow crossing between the bases of the antennæ, ocelli slightly nearer the hind border and about equally distant from each other and from the eye. Antennæ 9-jointed, those following the third becoming more slender and setaceous. Eyes narrower, the larger part visible from below, red-brown appearing transversely barred, front tumid, clypeus strongly convex, beak reaching to behind 2nd coxæ. Two rows of black spines at tip of hind tibiæ. Length 5 to 6 mm.

This species is quite easily distinguished from *lineatus* in the final instar by the difference in the shape of the head. In *spumarius* this is distinctly wider than long so as to appear bluntly pointed and the transverse furrow is longer than the distance from its center to either the front of vertex or to rear margin. The body as a whole appears broader and the color is usually fairly distinct, *spumarius* having a yellowish tint while *lineatus* is green with dusky or smoky tint.

The adults present many varieties and most of these have been found in Maine. Several are figured in the accompanying plate (fig. 47) which shows also at bottom one of the nymphs.

There is apparently no relation in these varieties to the food plants as different varieties have been found to mature from nymphs feeding on the same plant. Furthermore individuals of different color varieties are found mating together, apparently without any reference to color pattern.

The typical form of the adult is easily seen from the figures, the head bluntly angular, the body elongate oval, widest about the middle, the elytra extending well beyond the end of the abdomen and the length from five to six millimeters. The color varies from pale gray to black and the markings in the form of irregular spots, broken cross bands, or longitudinal stripes.

Grass-feeding Froghopper.

(*Philaenus lineatus L.*)

This species appears to be a distinctly grass-feeding species and as noted in the preceding section seems unable to maintain itself on plants outside the grass family.

The species has a wide range in the northern hemisphere occurring over a wide territory in Europe and North America, but in the United States appears to be distributed especially through the northern portion, occurring from Maine to the Rocky Mountains. It seems to occur in greatest abundance in the New England States and, in meadows which are kept in grass for a number of years in succession, it undoubtedly must be ranked as a distinct pest. While seldom if ever alone in its attacks, being associated with various jassids and other sucking insects, it is one of the abundant forms and during the two seasons in which I have had opportunity to observe it there has been no question as to its numbers being sufficient to occasion distinct loss. The records of injury to certain fields apply with special emphasis to this species as it was so plentiful that the frothy masses were a conspicuous feature of the meadows in June and early July. Timothy and redtop were apparently about equally sought and the froth masses occurred from the level of the ground to several inches above.

The withering of the upper part of the stems and probably a considerable part of the blasting of the heads, some of which is doubtless due to thrips (*A. striatus* Osb.) or to Jassids may be attributed to this attack.

At the time of my arrival in Orono, the last of June, the nymphs had largely reached the final stage of growth so that I do not have observations on the earliest appearance. Judging by their maturity however and also by the stages of growth shown in the related *P. spumarius* it is probable that the eggs hatch and larval life begins in late May or early June.

On June 27th, 1914, at my first opportunity for personal observation the species was found plentifully on timothy and redtop, all found being in the nymphal stages and included in the froth masses, sometimes as many as two or three of the froth masses and included larvæ on a single grass stem. The most

mature at this time was one with the wing pads developed evidently in the final nymphal instar. The final instar occupies a period of two or three weeks and corresponds closely with the time of rapid growth and formation of heads in the grass, the nymphal stage being passed and adults beginning to appear at about the time of hay cutting July 3rd to 10th.

The mature nymphs are easily distinguished from those of *spumarius* by the more slender body, the narrower front portion or inflated part of the head and by a more dusky coloration, especially as they approach moulting.

The process of emergence is interesting and apparently varies slightly in different individuals, but in cases observed the emergence occurred within the froth masses. The nymphal case is included within the remnant of the froth mass that remains attached and clings to the grass stem for some time. The head is closely appressed to the stem and directed toward the upper part of the stem, the abdomen is elevated and this and the thorax are both split along the dorsal line. The front legs clasp the stem, but the middle and hind legs are free.

The remnant of froth mass retains closely the original form and shows the form of individual bubbles, a condition which certainly points to the presence of some content that gives a gelatinous consistency to an otherwise watery mass.

The full life cycle of this species has not been followed and there are several points in the cycle which it will be especially interesting to determine. Nevertheless, enough is known concerning certain of the most critical periods of development to furnish a basis for the application of certain measures of control.

That the winter is passed in the egg stage as has been generally stated and is evidenced by the occurrence of larvæ in our cages, placed in early spring over timothy grass in meadows. Adults certainly could not have entered there to deposit eggs in spring and if adults had hibernated in the grass we should have found some at least of the dead bodies present within our cages.

The date of egg hatching cannot be given precisely, but the earliest appearance of the froth masses in June would indicate a rather late hatching, at least for this latitude.

During June only young are to be found and during this period they pass through three or four moults. Three instars at least are represented in material collected June 19th, 26th and 27th.

In rearings from nymphs collected on grass the latter part of June adults were secured during the first week in July. In one case a nymph enclosed June 29th moulted July 1st and emerged as adult on July 5th and in another case a nymph probably recently moulted caged July 9th, developed to maturity and adult emerged July 11th. These all indicate a short nymphal period and rapid growth.

The adults continue to feed and up to July 29th no signs of egg maturity or egg deposition had been noted. Egg development is evidently slow and mating and egg deposition must occur irregularly, probably extended over a period of some weeks in autumn.

Ovaries from females, collected in the field, were dissected and four well developed eggs were found with definite shell, but no evidence of segmentation. A number of apparently undeveloped eggs were in the ovarioles.

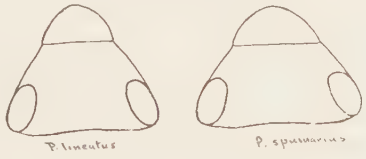

Fig. 39. Relative form of head in *Ph. lineatus* and *spumarius* nymphs of final instar.

Comparing the final instar especialy with *spumarius* the head is longer and the front more distinctly produced. In *spumarius* the part in front of the suture is in the ratio of 10 to 24 while in *lineatus* it is as 11 to 20 and the head entire in *spumarius* is in ratio of 44 wide to 31 long in *lineatus* as 40 wide to 34 long as taken in average for several specimens.

Lineatus is further distinguished by the dusky coloration especially toward the posterior end of the body as the nymph approaches maturity.

Some very small specimens of this species were taken at Saddleback Lake in the summer of 1916, the smaller ones only

4 mm. long, and many froth masses were noticed on the small dwarfed plants of Canadian bluegrass growing on rocky ledges. It seems possible that the depauperate condition of the grass and of the froghoppers living on it may be a mutual adaptation to a deficient food supply.

Adults of *lineatus* are distinguished from *spumarius* by the narrow, more parallel sided form and the longer head. The head is rounded angular in front and as wide as the thorax.

The color is gray with a whitish margin to the costa, bordered by a blackish line which fades out toward the end of the elytron. The length is from four to five millimeters.

Remedies or Control.

It seems very evident that the most effective control for this species lies in a frequent rotation from grass to some other crop and the general freedom from infestation in timothy meadows not older than two or three years as compared with the great abundance in old meadows, emphasizes this point.

This applies of course to many other of the grass insects, but on account of the restrictions of this species and the fact that the time during which eggs must be present is extended over a long period, it should be particularly effective. To be of greatest advantage plowing should be done in spring or late in fall.

It is recognized that there are many situations especially in wooded pastures and rougher meadow land where it is desirable to maintain a grass crop for a long succession of years and it is hoped that measures for reducing or eliminating these pests will make this possible without sacrificing such a large percentage of the crop.

Of the measures available for permanent meadows three seem worthy of mention and thorough trial.

While egg deposition has not been actually observed it is almost certain that the eggs are placed in grass stems and that they remain during fall, winter and early spring in this condition. It will be evident that burning of the surface dead grass, when this is allowable, will furnish a means of destroying the eggs of these and many other species.

Hopper dozer treatment immediately after haying to catch recently developed adults, would probably be the best time for use of this measure.

The hopper dozer method consists in the use of a strip of sheet iron, ten or fifteen feet in length, coated with coal tar or tanglefoot, and drawn over the surface of the grass land with about the rate of a rapid walk. Its success depends upon the fact that the hoppers when disturbed jump up a few inches from the grass and this means that they will usually fall back upon the sticky surface and be caught. The tar or tanglefoot must be replaced as often as it becomes so loaded with insects as to permit them to escape.

Early mowing would probably reduce the number materially and where the insects are abundant the gain in later growth would probably compensate for loss in quantity of crop. A trial of this was attempted, but circumstances delayed the first mowing till the bulk of insects were ready to become adult, so no conclusive results were secured.

That such mowing would be of service is indicated by the entire absence of these insects on lawns where early and frequent mowing is the practice.

Angulated Froghopper.

(*Lepyronia quadrangularis* Say.)

This species is not an abundant one in Maine, and apparently has no particular economic importance, but since it resembles the common meadow froghoppers it is desirable to show its distinctive characters.

It has not been observed, except in the latter part of the season, and so far as present evidence shows, there is a much belated single brood in the latitude of Orono, the larvæ of which develop during August, the adults being present during late August and through Sept.

Nymphs were first collected Aug 14th and included three well marked stages, representing evidently different instars and probably the second, third and fifth if the full series includes five instars. Adults appeared in the fields on the 18th, and a reared specimen was secured on the 17th from the nymphs collected on the 14th.

The nymphs are included in froth masses similar to those of the other froghoppers and are smooth and highly polished light green in color, becoming slightly more yellowish in later stages, the head distinctly blunt, almost truncate in front and the front somewhat flattened as compared with the bulbous form of the species of *Philaenus*.

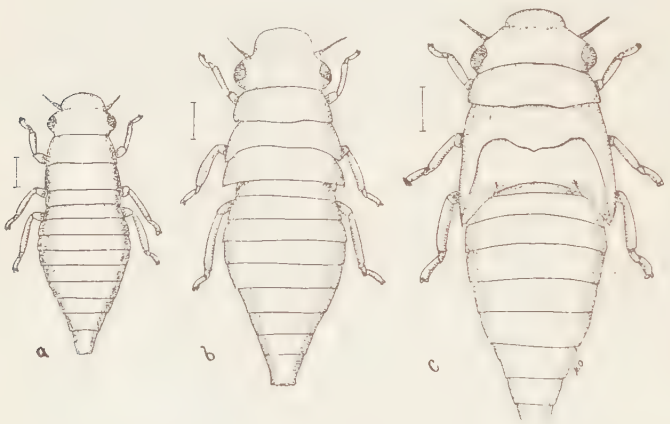

Fig. 40.

The smallest individuals taken (2nd instar?) *a*, Fig. 40, are 4 mm. long, tylus broad and distinctly truncate, beak reaching base of abdomen, the meso- and metathorax with no distinct development of wing pads, the color light green. The abdomen is pyriform, a little wider on third segment than thorax, the legs nearly uniform in size, the third pair slightly larger.

The next larger individuals (3rd instar?) *b*, Fig. 40, are 5-6 mm. long, similar in shape and color to the preceding stage, but with the wing pads clearly indicated, those of the mesothorax extending only slightly over the hinder ones, the beak reaching to the third coxæ.

The final nymphal instar (5th?) *c*, Fig. 40, is 6 to 7 mm. long, based on measurement of three individuals, light green in color with slightly more of yellowish and with the wing pads which extend to base of third abdominal segment of yellowish or whitish color. The beak extends to base of third coxæ, the legs nearly uniform in size, the hinder pair only slightly larger than the middle and the middle a trifle larger than the front

pair, the head is broadly cordate, the eyes prominent, and the front similar to the preceding stage with a slight production of the anterior border.

In all stages the pleural lobes of the abdominal segment are very large and occur on all segments to last, enclosing a broad, deep channel which, as in related species, doubtless serves especially in the enclosing of air to form the froth mass.

This species is often taken in autumn in sweeping in grass lands and probably has a variety of food plants, though so far the nymphs have been found only on the *Impatiens biflora*. The adults have been taken only in autumn and while it would be unsafe to say that no spring generation occurs, the facts at hand would indicate that there is a late deposition of eggs in fall and that these eggs remain unhatched until midsummer of the following year, then producing nymphs during August, or possibly in late July, which mature very rapidly and give rise to adults by the middle of this month.

While the nymphs of this species very closely resemble those of *Philaenus* they may be at once distinguished by the blunt form of the front part of the head, appearing from above as if the head had been pushed against some object and a circular form made broadly truncate.

Adults of this species have a quite characteristic appearance with strongly sloping elytra which bear a blackish marking, the angle of which touches the costal border. The general color is gray with often a dull suffusion of purplish or brownish tint. Length 6 mm. to 7 mm.

BUSH AND TREE FROGHOPPERS.

Parallel Spittle Insect.

Aphrophora parallela Say.

Although this insect is a very abundant one and has been known to American entomologists for nearly a century, there has been very little written about it nor any careful study of its life cycle and habits.

About the only account of its habits worthy of mention is the original description by Fitch published in the Transactions of the New York State Agricultural Society for 1857.

This account is brief and while it has been reproduced in Packard's Forest Insects neither of these works is so generally available at present as to be accessible to all who might wish to see it, and it seems desirable therefore to quote it here.

"In June, a spot of white froth, resembling spittle, appearing upon the bark near the ends of the branches, hiding within it a small white wingless insect having six legs, which punctures and sucks the fluids of the bark, and grows to about a quarter of an inch in length by the last of that month, and then becomes a pupa of a similar appearance, but varied more or less with dusky or black, and with rudimentary wings resembling a vest drawn closely around the middle of the body; the latter part of July changing to its perfect form with wings fully grown, and then no longer covering itself with foam, but continuing to the end of the season, puncturing and drawing its nourishment from the bark as before. The perfect insect, a flattened oval treehopper, 0.40 in. long, with its wing covers held in form of a roof, its color brown from numberless blackish punctures upon a pale ground, a smooth whitish line along the middle of its back, and a small smooth whitish spot in the center of each wing cover, its abdomen beneath rusty brown."

This short account while giving the main points in the life cycle of the insect leaves many points to be desired and it was in hopes of supplying some of these wanting details that observations were begun upon the species in the summer of 1914.

At this time the nymphs in their frothy masses were quite plentiful on the Scotch Pines on the University Campus and it was hoped that by watching their development to verify the connection between these nymphs and the adult form. As stated by Fitch the nymphs were attached near the tips of the twigs and their presence was made very manifest, not only by the frothy masses, but by the sappy exudations running down on the branches so that there was a distinct discoloration. Usually only one nymph was observed on a twig and these were scattered over the tree. A number were enclosed in cheese cloth coverings to secure adults, but most of these were removed by some one who evidently counted them unsightly. However the rearing of some individuals and the securing of others either in process of emergence or in close proximity to the cast off skins leaves no question as to the larvæ observed being the young of this species.

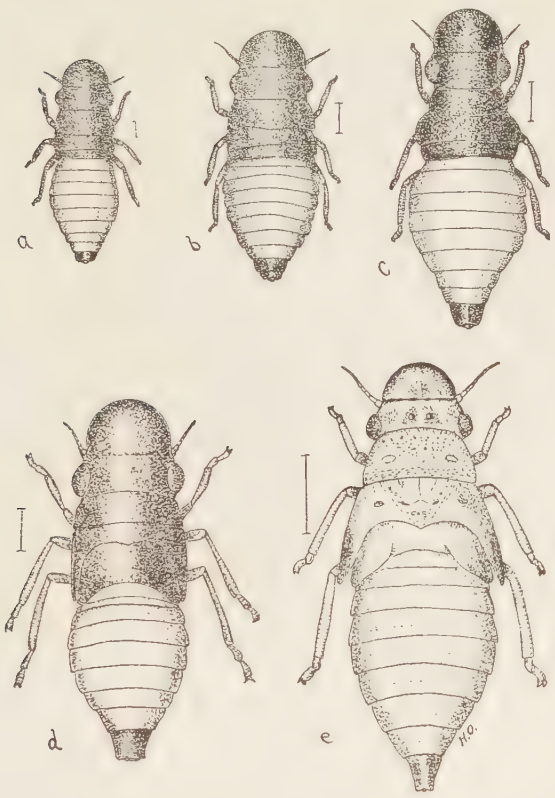

Fig. 41. *Aphrophora parallela a, b, c, d, e,* 1st, 2nd, 3rd, 4th, 5th instars. All enlarged. (Original.)

The earliest nymph collected in 1914 was a partly grown one secured by Mr. Newman June 19th, evidently representing the next to the last instar as all the later and larger nymphs showed a different color pattern. The date of egg hatching is therefore uncertain, but is probably during the last of May or early in June. The nymphal growth must be fairly rapid as individuals of the last instar occurred in early July and the first adults were observed on the morning of July 15th, one male being caught and another observed. At the same time one of the earlier instar forms was observed but at this time nearly all were in the preimago stage.

For the summer of 1916 which was late and the insects probably delayed in development, specimens were secured June 14th,

that represent still earlier stages and the smallest an individual but three and one-half millimeters long is probably the first, while a larger one, four and one-half millimeters long, may represent the second instar. These complete a fairly regular series from which we may present a brief statement of distinctive characters.

Description of Early Stages.

First instar. Smallest individual seen, length 3.5 mm. Body slender, abdomen scarcely wider than thorax. Head and thorax with antennæ and legs and the last segment of the abdomen black polished. Abdomen except last segment yellow. Antennæ short, first joint thicker, about as long as thick, second scarcely longer than first, enlarging to tip, third short and with the following joints forming an obscurely segmented terminal part, tapering slightly to a blunt tip.

The second instar as indicated by size and maturity is 4.25 mm. long with the color as in the first instar, but with a very slight indication of beginning of the wing pads of the mesothorax.

The third instar 5 mm. long has the coloration of the preceding stage, but there is a distinct enlargement of the mesothorax into developing wing pads, but scarcely any for the metathorax.

Fourth instar. Length 6 mm. Head strongly produced semicircular from the base of the antennæ. A transverse suture across head, touching bases of antennæ. Mesothoracic wing pads extending back and enclosing metathorax and nearly touching base of abdomen, metathorax strongly concave behind the wing pads, not specially developed.

Color: Head and thorax including wing pads fuscous or nearly black, shining. Segments of the abdomen except the terminal one yellow-white, terminal segment black, tubular, legs black, tips of femora paler. Beneath; front black, lower part of face, legs and central stripe of abdomen brown, sides of abdomen, segments 1 to 5 orange red. (See fig. 41 *d*.)

Final instar. Length 11 mm., width 4 mm. Yellowish white with brown spots, brown eyes, ocelli in brown spots. A pair of spots on the prothorax, median and lateral spot on scutellum, part of mesothorax, the border and a pair of spots near center and the hind borders of the wing pads dusky; terminal seg-

ment black. Antennæ, eyes, tip of beak, and tarsi blackish. Ventral expansion of the pleurites giving a broad channel beneath, narrowing to tip where they form the leaf-like plates used in enclosing air to form the bubbles. (See fig. 41 *e*.)

Alder Spittle Insect.

(*Clastoptera obtusa* Say.)

This common species abundant over a large part of the northern United States has been known for a long period and while described and credited to alder it is found on a variety of plants mostly shrubs. Considerable confusion has occurred in its classification and Fitch described certain forms as *pini* and *testacea* from rather marked forms occurring on different plants, but Ball in his review of the group referred all these to *obtusa*. No distinct varieties have been clearly demonstrated as restricted to any host plant.

Linter Fifth Report of the State Entomologist of New York gives an account of the species based on larvæ occurring on alder. He describes the larvæ as nearly white with long

Fig. 42. *Clastoptera obtusa* Say. Nymph of last instar. Enlarged. (Original.)

legs which were moved rapidly in walking. The pupæ (last nymphal instar,) which had but recently undergone their transformation, show but little coloring, especially on their wing pads. With increased age they become more deeply colored, and they are olive-green on their thorax, wing cases and legs."

While the observations of this season add little to the past records, the fact that specimens were bred from white birch and hazel seems to make a record worth while.

Our specimens were taken as last instar nymphs on July 25th at which time they were beginning to change to adults and adults have been common on various plants since to early August. See fig. 50, *e* and *f*.

Records carry the species as adult as late as Sept. 5th, so it may be considered certain that there is a single generation in this latitude and that the winter is passed in the egg form, the eggs hatching in spring or early summer, probably in June or early July, and the larval stages are passed rapidly.

Dog-wood Spittle Insect.

(*Clastoptera proteus* Fitch.)

As the specific name implies this species is extremely variable and occurs in several forms, the more common ones being black in color with bright yellow cross bands on the thorax, in some cases with bright yellow spots on the base of the elytra and in others without these spots. See fig. 50, *g*, *h*, and *i*.

The species is supposed to occur on a variety of plants, but at Orono it has been taken for the larval stages, especially on the dogwood. Nymphs of apparently the final stage were taken during the summer of 1914 and adults were reared from these of both the color varieties. In 1916 still younger nymphs, the smallest found about two millimeters in length, were taken on dogwood and these are the smallest that have been secured. These were taken July 2nd, 7th and 10th and represent evidently individuals that have hatched from eggs that have survived the winter as no trace of earlier generation or of hibernating females has been found. These earlier nymphs agree closely with the older nymphs observed in 1914 except that the head and thorax are nearly black or solid dark olive green, while the abdomen is clear white or a very light greenish white. The beak extends to the hind coxæ and is dusky greenish olive, as are also the legs which are of about uniform size, or the hind ones possibly a trifle the larger.

Five fairly distinct sizes or forms representing probably as many stages are included in the series, but there is very little

difference in them except in size, the greater amount of the dark color and the appearance of the wing pads.

Evidently they pass by easy gradations from one instar to another. Probably the moults take place within the froth masses as occasionally moulted skins may be found in the froth masses, but the nymphs appear to move readily from the froth if disturbed and start a new mass at another point. This habit of froth forming is so strong that they will begin the liberation of air bubbles in the balsam solution if placed in it alive for mounting.

The difficulty of securing newly hatched individuals is obvious since the only indication of occurrence is from the masses of froth and these do not appear until the young have fed and presumably have attained some increase in size.

The smallest individuals represent, therefore, probably advanced individuals of the first instar or possibly newly moulted individuals of the second instar. They are about two millimeters long, the head, prothorax, and mesothorax, with legs, antennæ, and last segment of the abdomen dark olive green, the metathorax and abdomen except last segment, greenish white or nearly pure white. There is no trace of enlargement for the wing pads and the metathorax is very short and inconspicuous.

The second size of individuals, probably second instar, show dark color on the metathorax and the angles of meso- and metathorax appear scarcely swollen.

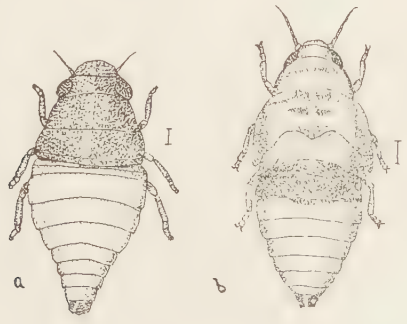

Fig. 43. *Clastoptera proteus* Fitch. Nymphs of 2nd or 3rd and final instar. Enlarged. (Original.)

The next in size, the third instar (?) show extension of mesothorax into the beginning of wingpads, but no perceptible pads on the metathorax. The dark color extends on to the first, second, and middle of the third abdominal segments, but is uniformly dusky on pro- meso- and metathorax.

No distinct separation of fourth and fifth instars has been made, but individuals referred to these differ in having less solid dark marking on the thorax and more extension of color on the abdomen. The wing pads are much more developed, and in the more mature forms extend on to the base of the abdomen. These mature forms, which are about three and a half millimeters in length, give rise to the adults, the appearance of adults coming the latter part of July.

Putting the various records together, it appears that the eggs remain over winter, the nymphs appear in late June, mature by the latter part of July and the adults presumably lay eggs during the latter part of the summer. There seems very little probability of a second brood in the latitude of Orono.

While these insects sometimes occur in considerable abundance and their food plants are often utilized as ornamental shrubs there is little danger of their becoming so serious a pest as to require any particular treatment. Indeed so far as observations go they seem pretty generally confined to the bushes, growing in their natural habitats and have not been taken upon bushes growing under cultivation.

Clastoptera xanthocephala Germ.

This small species while more southern in distribution occurs in some parts of New England, and may at times be found in Maine. It is a very small species, about three mm. long, and black or dark brown, resembling the black varieties of *proteus,* but differing in having slender lines across the upper part of the face and the lower part including the clypeus is black.

According to Mr. Heidemann it has been found during the nymphal stages on Chrysanthemums, although he surmises that the original food plant may have been Ragweed. In either case it can hardly be counted as of any particular economic importance in Maine.

Philaronia bilineata Say.

Another species which may be mentioned as belonging to the Maine fauna, although it has not been found in any abundance in the State, is the two-lined spittle insect *Philaronia bilineata* which is a common species through the northern part of the country from the White Mountains to the Rocky Mountain region. It is a little larger and more robust than *Philaenus lineatus* but much like it in general appearance. It has been taken at Fryeburg in the western part of the State by Mr. C. P. Alexander. The species has never been treated as of special economic importance and it is evidently too rare in Maine to need economic attention, but it often occurs in large numbers on the vegetation of the plains in the Dakotas and Montana.

Cercopidae Occurring in Maine.

A list of the species of this family known to occur in the state may be of service in connection with the study of the leaf-hoppers (Jassoidea) and the studies of the life histories of some of the more important species from an economic standpoint.

The froghoppers are recognized by the conspicuous circle of spines at the tip of the hind tibiæ and the species occurring in this region are mostly rather small insects of modest colors, and the young are well known on account of the masses of froth in which they are enclosed.

The tree living or shrub living species are included in the genera *Aphrophora* and *Clastoptera* while the species occurring on grasses or low herbage are included in the genera *Philaenus* and *Lepyronia*.

Aphrophora parallela Say. Occurs on pine, often abundant.
Aphrophora saratogensis Fitch. Also a pine species is less frequent.
Aphrophora quadrinotata Say. Not abundant in collections so far.
Philaenus spumarius L. A very abundant species in meadows and mixed vegetation, living on other plants than grasses.
Philaenus lineatus L. Very common in meadows and grass land living on various species of grass.
Lepyronia quadrangularis Say. Much less common here than the preceding species but evidently not a grass feeding species.
Philaronia bilineata Say, Fryeburg. (C. P. Alexander)
Clastoptera obtusa Say. A common species on alder, etc.
Clastoptera proteus Fitch. Common on dogwood.
Clastoptera xanthocephala Germ.

Of these species only the *Philaenus lineatus* and *Aphrophora quadrinotata* have been given a record for Maine in Ball's Monograph of the North American species, but *spumarius* is recorded for Nova Scotia and "New England States."

Fig. 44. Buttercup affected by *Philaenus spumarius*. The shriveled blasted heads are indicated by the x. (Original photograph.)

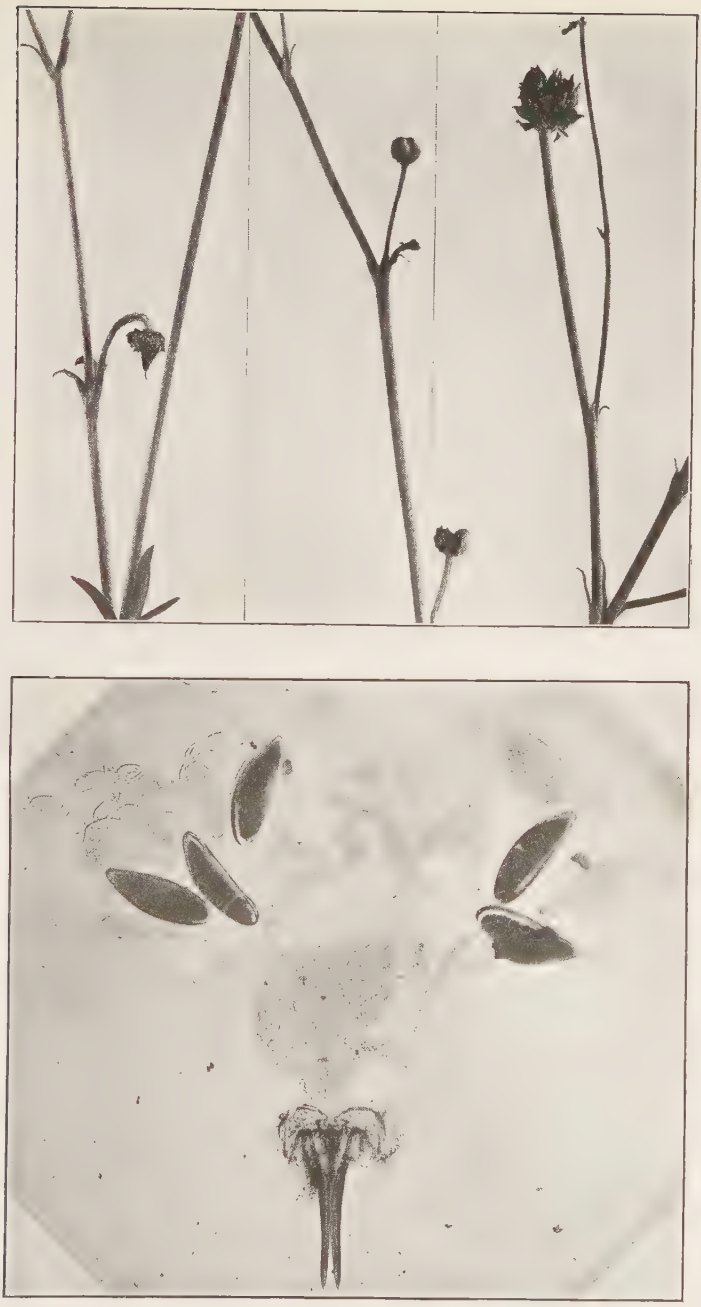

Fig. 45. Buttercup heads enlarged showing the blasting due to attacks of the Froghopper *Philaenus spumarius*. Fig. 46. Female reproductive organs of *Philaenus spumarius* showing ovary with undeveloped, partially developed and mature eggs, the latter appearing very black, with shell. Below these and connected with the oviduct is the circular spermatheca and at bottom the ovipositor. (Original photographs.)

Fig. 47. Varieties of *Philaenus spumarius.* 1, 2, 3, var. *fasciatus;* 4, 6, *leucocephalus;* 5, *pallidus;* 7, *lineatus;* 8, nymph in final (fifth?) instar; 9, dark form of *leucocephalus.* (Original photograph.)

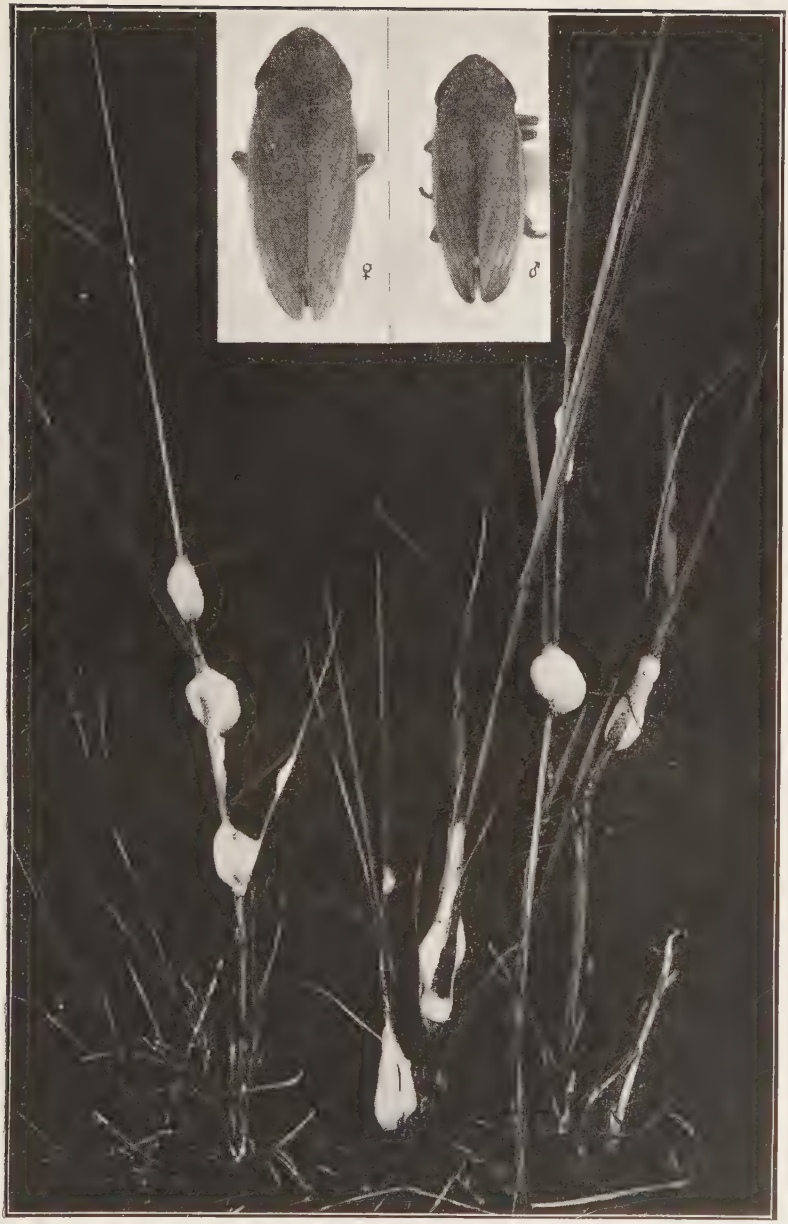

Fig. 48. *Philaenus lineatus*. Male and female above. Grass stems showing froth masses attached about natural size. (Original from photographs.)

Fig. 49. Froth masses of *Philaenus lineatus* enlarged about three diameters. (Original from photograph.)

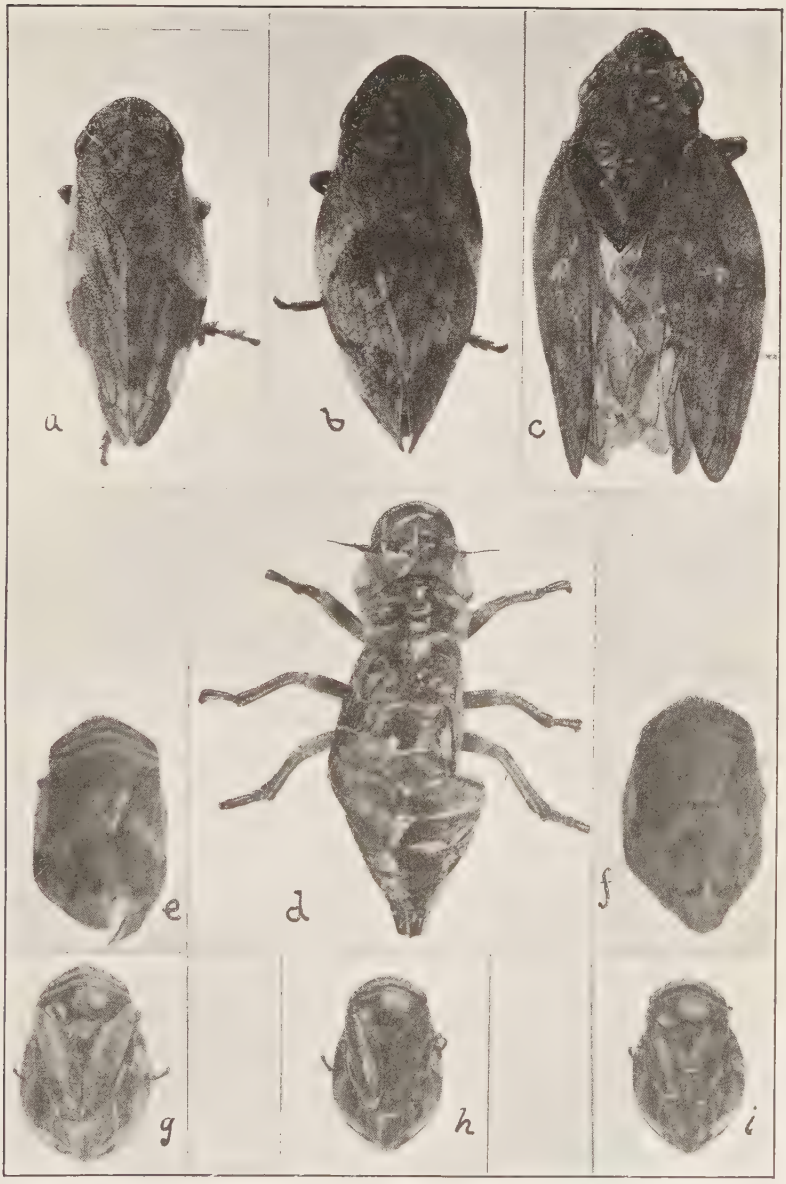

Fig. 50. *a, Aphrophora quadrinotata; b, Lepyronia quadrangularis; c, Aphrophora parallela; d A. parallela.* Nymphal molt from last instar; *Clastoptera obtusa* Say; *e,* male; *f,* female; *Clastoptera proteus* Fitch, *g,* female; *h, i,* two varieties of male. (Original.)

Maine Agricultural Experiment Station

ORONO

BULLETIN 256 NOVEMBER, 1916

ELM LEAF ROSETTE AND WOOLLY APHID OF THE APPLE.

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†In collaboration with U. S. Department of Agriculture.

BULLETIN 256.

ELM LEAF ROSETTE AND WOOLLY APHID OF THE APPLE.*

Schizoneura lanigera (*americana* in part).

EDITH M. PATCH.

White masses looking like patches of thick mold often occur on apple trees, especially about pruning wounds or other scars on the trunk and branches and upon water sprouts. Beneath this substance are colonies of rusty colored or purplish brown plantlice known as "woolly aphids" on account of the appearance of white covering which is, however, really composed of waxen filaments.

The species is common in Maine on hawthorn, mountain ash, and Baldwin and some other varieties of apple.

It is one of the migratory aphids and passes part of its life cycle upon the elm,** as is explained in the following treatment. It should not however, be confounded with those woolly aphids found upon alder† and maple,‡ as the woolly aphid of the apple cannot live upon those trees.

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*Papers from the Maine Agricultural Experiment Station: Entomology No. 91. The work upon which this bulletin is based was for the most part completed in 1913 and published by this Station as Bulletin 217, which is now out of print. As the interest in the insect concerned continues and as the discovery of its annual migration from elm to apple was first recorded by this Station, it seems desirable to print this revised edition of Bulletin 217, containing such changes as bring the subject down to date. CHAS. D. WOODS, *Director*.

**There are other elm aphids belonging to this same genus which do not migrate to apple.

†*Pemphigus tessellata* (*acerifolii.*)

‡*Pemphigus tessellata* (*acerifolii*) and *Pemphigus aceris.*

Habits and General Discussion.

The woolly aphid occurs upon the apple as a bark feeder and is found upon branches, roots, and tender places on the trunk. These insects are covered by a white flocculent waxy secretion given off as fine filaments through pores in the skin and their colonies are thus readily detected by the masses of white "wool" which renders them conspicuous. Figs. 58 and 67.

On the roots its attacks induce enlargements and in the creases of these malformations the root form occurs in clustered masses. The injury to the trees is due both to the sucking up and exhaustion of the vital plant juices and to the poisoning of the parts attacked, as indicated by the consequent abnormal growths. Fig. 66.

The damage is particularly serious in the case of nursery stock and young trees and is less often important after the tree has once become well established and of some size, though it may be troublesome then, too. Where this insect is abundant all the roots of a young tree to the depth of a foot or so become clubbed and knotted by the growth of hard fibrous enlargements with the results in a year or two of the death of the rootlets and their ultimate decomposition with subsequent disappearance of the galls and also of the aphids, so that after this stage is reached the cause of the injury is often obscure.

On the trunks the presence of the aphids results in the roughening of the bark or a granulated condition which is particularly noticeable about the collar and at the forks of branches or on the fresh growth around the scars caused by pruning, which latter is a favorite location. On the water shoots, they collect, particularly in the axils of the leaves, often eventually causing them to fall, and on the tender growth of the stems. The damage above ground, even when insignificant, is useful as an indication of the probable existence of the aphids on the roots. A badly attacked tree assumes a sickly appearance and does not make satisfactory growth, and the leaves become dull and yellowish, and even if not killed outright it is so weakened that it becomes especially subject to the attacks of borers and other insect enemies.

The common forms both on the roots and above ground are wingless aphids, not exceeding one-tenth of an inch in length,

of a reddish-brown color, and abundantly covered, especially in those above ground, with a flocculent waxy secretion. Fig. 63.

In August and later, among the wingless ones, winged females appear in abundance. Fig. 62. They are little, clear-winged aphids which look nearly black unless carefully examined when the abdomen is found to be dark yellowish red or rusty brown. These are the fall migrants that leave the apple and seek the elm before giving birth to the generation of true sexes,—minute, wingless, beakless creatures, the female of which deposits a single "winter egg" within a crevice of the elm bark.

The flight of the fall migrants away from the apple is apparently a common observation of all who have studied this species either in this country or abroad,* but it is only recently that the significance of this flight has been appreciated, it having been thought previously to be merely a dispersal from one apple tree to another.

Where woolly aphid colonies are very thick, the true sexes and the winter eggs are sometimes found upon the apple tree. That such occurrences are accidental seems probable as fall migrants of most species will occasionally dispose of their progeny before reaching the appropriate winter host.

A record of such an occurrence is to be found in the *Report of the Entomologist of the United States Department of Agriculture for the year 1879* by J. Henry Comstock. On page 259 of this Report, Dr. L. O. Howard recorded his observations made in a little orchard of Russian apple trees then on the grounds of the Department of Agriculture at Washington, his statement concerning the winter egg being as follows:

"The winter egg was found on several occasions during the winter in crevices of the bark over which a colony had been stationed during the summer. It was a rather long ovoid, measuring .322 mm. (.125 inch) in length and was very similar to the winter egg of *Colopha ulmicola* (Fitch), as described by Riley in Bulletin No. 1, Vol. V, Hayden's Survey.

"This egg was laid, as Professor Thomas supposes, by a wingless female, differing from the ordinary agamic form to a certain extent. These females we only know from finding their skins around the winter egg, since they often die without depositing it. The males we have not seen."

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*Dr. O. Schneider-Orelli records also the development of winged forms in June.

Sonderabdruck aus Heft 7/8 des XII. *Bandes der Mitteilungen der Schweizerischen Entomologischen Gesellschaft.* 1915.

Mr. A. C. Baker of the Bureau of Entomology wrote me (Nov. 20, 1912): "I found that when the colonies are very thick the alate forms often stay on the apple and I have found on one tree a number of winged ones with the abdomen shriveled as it is after producing sexes. I saw some sexes crawling up and down the small twigs and though I have not yet seen any eggs which they laid they no doubt would lay eggs. On one occasion I found sexes on an apple leaf which had fallen to the ground."

That such occurrences are not a part of the ordinary life cycle is indicated by the usual wholesale flight of the fall migrants.*

On the elm the stem mother, which hatches from the overwintering eggs sheltered probably in rough crevices of the bark, appears early in the spring and may be found in Maine before the middle of May stationed on the partly opened leaf buds.

The beak punctures on the rapidly expanding new leaves cause an unevenness of growth which forms a protection for the aphid. By the last of May the earliest of these wingless stem mothers are mature and found in the deformed elm leaves (Fig. 59) producing the next generation. The antenna is shown in Fig. 68.

These nymphs, like the stem mother, are a wingless form and they become fully developed about the tenth of June. They have wax glands, of the type shown in Fig. 61. Their progeny are the third generation and attain wings. These winged aphids are known as the spring migrants.

It takes three weeks or slightly more or less, beginning about the twentieth of June, for all the individuals of this third generation to get their growth so that the migration covers a considerable period. The deserted rosette or leaf cluster at this time looks like Fig. 60. During this time these winged aphids may be found alighting on the leaves of apple, mountain ash,

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*1904. Alwood, Wm. B. Circular in Relation to Some Injurious Insects and Plant Diseases. Special Bulletin (C. P. C. 45), Va. Exp. Sta.

1908. Gillette, C. P. Notes and Descriptions of Some Orchard Plant Lice, of the Family Aphididæ. Journal of Economic Entomology, Vol. 1, pp. 306-308.

1909. Börner, Carl. Kaiserliche Biologische Anstalt für Land-und Forstwirtschaft, August.

1913. Reh, L. Der Praktische Ratgeber im Obst—und Gartenbau, February 2.

and hawthorn. They creep to the under side of the leaf and remain there while they give birth to their progeny (i. e., the fourth generation). These young, before they feed at all, crawl to the stem of the water-shoots, or to some tender place on the bark often near a pruning wound, and there start the colony on the summer host plant. Such a young colony shown in Fig. 67, was on a mountain ash in Orono of which I kept a record during the season of 1912.

The main trunk of this tree was dead nearly to the ground, but 12 vigorous shoots had grown up measuring about 5 feet each. On June 28 this mountain ash had about 150 woolly masses of nymphs grouped on the stem at the leaf axils. These nymphs ranged from very tiny ones to half grown insects, none being mature at that date. One such woolly mass contained 155 individuals of various sizes. (See Fig. 67). On the ventral surfaces of the leaves of this mountain ash were stationed many elm leaf migrants producing there their broods of nymphs which could be seen, with the hand lens, to be augmenting the woolly masses on the stem. Collections of these migrants thus stationed were made as follows:—July 2, 88 migrants; July 3, 211 migrants; July 5, 92 migrants; July 8, 54 migrants; July 9, 80 migrants; July 10, 33 migrants; July 11, 14 migrants; July 12, 3 migrants. Only living individuals were collected, dead ones being brushed off and discarded in the counts. Microscopic examination showed them to be identical with winged forms collected in elm leaf. Two large elm trees with leaves well stocked with this species stood about a rod distant.*

In this connection it may be of interest to record a forced migration test. On June 21, 1912, I placed several hundred elm leaf migrants at the base of water shoots of an uninfested mountain ash on the Campus. As the migrants are much more docile about sundown than earlier in the day this was done about 7 P. M. They moved but little, most of them creeping to the ventral side of a leaf and remaining there; and during the night producing nymphs which sought the leaf axils of the water shoots so that by the afternoon of June 22, the tiny nymphs had already fed enough and secreted enough white wax to give the typical "woolly" appearance to the young colonies. These and the progeny thrived on the mountain ash in a perfectly normal way.

On June 17, 1913, a laboratory cage check was started with migrants from an elm rosette. The winged forms ready to desert the elm leaves were caged with a seedling mountain ash. Their progeny settled in woolly masses on the stem of the seedling and are shown in Fig. 58. By July 2 these had matured and were producing young which in turn had matured and were producing nymphs on July 26. This third mountain ash generation (sixth generation beginning with the stem mother)

*Previously recorded in Journal of Economic Entomology, Vol 5, No. 5, 1912.

proved too much for the little seedling which was so nearly dead by August 10 that the last of the aphids perished at that time.

Schizoneura americana is a name which until recently has been commonly applied to two distinct species by American entomologists.

One of these species inhabits the leaf cluster or aphid rosette of the American Elm (Figs. 59 and 60). This migrates to apple, several varieties of mountain ash (*Pyrus* sp.) and to hawthorn (*Crataegus*), where it was familiar as *lanigera* long before its identity with the aphid of the elm rosette was suspected. The life cycle of this species so far as personally ascertained by the writer is recorded in the present paper. This species is found in Maine, Missouri, Colorado* and doubtless all the way between. Like other aphids it is fluctuating in its abundance, being conspicuous some years and comparatively rare during other seasons.

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*That Messrs. Gillette and Bragg were mistaken in their opinion that the rosette aphid in Colorado did not migrate to the apple in accordance with its habit in Maine (*Journal Economic Entomology, Vol. 8, p. 100*) is shown by the observations of Mr. Maxson (*Entomological News, Vol. 26, pp. 367-368*). Although Professor Gillette has not yet published his later observations, so far as we know; that they agree with those of Mr. Maxson is indicated in a letter from him to the writer under date of June 25, 1915, from which the following paragraphs are quoted:

"You will be interested to know that the rosette form of the elm *Schizoneuran* is very common about Fort Collins this year, and the winged forms are now leaving the leaf clusters in great numbers, and for the first time since we began the study of this insect, we find the lice locating in considerable numbers upon the under side of the leaves of apple trees.

"In many instances we are able to find the young that they are depositing, and in many instances, also, it seems probable that a colony of young lice in the axils of the leaves are the product of these winged lice from the elm. So it begins to look as though we shall have to admit that there is a natural migration of this elm *Schizoneuran* to our apple trees.

"We had been able, repeatedly, to get these lice to take in small numbers in our breeding-cages, and I find that last year Mr. Maxon of Longmont had found this louse going to the apple in the field, but until a few weeks ago, he had not communicated the fact to me. It really looks now as though our observations here would fully confirm your observations in Maine."

The experiments of Mr. Baker proved that in the localities in which he worked the elm is the winter host of *lanigera* (*Report No. 101, U. S. Department of Agriculture, Office of the Secretary. 1915*). The life cycle of this aphid, therefore, as discovered for Maine by the writer, does not seem to be exceptional for America.

The other species to which the name *Schizoneura americana* has been commonly applied is the aphid discussed in Bulletin 241 of this Station. Since the name *lanigera* takes care of the rosette species on elm as well as on apple, *S. americana* seems to be left conveniently for the aphid curling or rolling the leaf of the American Elm (Fig. 45 of Bulletin 241). Riley's description of the leaf deformations caused by *S. americana*† indicates clearly enough that he originally applied this name to both these species as his successors have certainly done until recently; and the synonomy *"Schizoneura lanigera* (*americana* in part, of authors)," correctly designates the "rosette aphid" of the elm.

There are apparently 3 summer generations of progeny of the elm leaf migrants upon the apple in Maine,—two apterous generations followed by a generation part of which, the fall migrants, become winged and leave the apple and part develop into apterous forms and remaining on the apple give birth to nymphs which while still young seek protection at the base of the tree for the winter and are known as the hibernating nymphs.

It is the function of the migrants to seek the winter host and there give birth to the true sexes. These are the tiny yellowish brown egg-laying females and the still smaller pale yellow males. Both sexes are wingless and with rudimentary mouth parts which are apparently functionless. One comparatively large yellow egg occupies nearly the whole abdomen of the female and with the deposition of this the cycle of the species closes,—or begins. It is too complicated a performance to follow easily but the outline on page 338 will be useful as a summary. Such a cycle with the annual migration to and from the apple with the elm serving as host for the first three spring generations is undoubtedly typical for *lanigera*. The hibernating nymphs which remain protected about the crown of the apple over winter and ascend to tender places on the bark before feeding in the spring give what looks like a "closed cycle" of apterous viviparous females persisting on the apple. How long

†"Curling and gnarling the leaves of the White Elm (*Ulmus americana*), forming thereby a sort of pseudo-gall. The curl made by a single stem-mother in the spring takes the pretty constant form of a rather wrinkled roll of one side of the young leaf, but according as there is more than one stem-mother, or as several contiguous leaves are affected, the deformation assumes various distorted shapes, sometimes involving quite large masses of the leaves."

such a colony could maintain itself on the apple without fresh material from the elm I do not know.*

I am certain that in Maine the natural enemies of the woolly aphid would cut its career short and that it would not assume the status of a pest of consequence if it did not shift its food plant. As it is, a two days quest in the vicinity of Orono early in September, 1913, failed to locate a single colony which was not well nigh demolished by chalcid parasites and the colonies of 1912 met a similar fate the preceding year by virtue of syrphus maggots. Lady bird beetles are also very active some seasons. While in the elm leaf this aphid is preyed upon by syrphus maggots, capsid bugs and lady birds.

As if the hibernating nymphs were not enough to bewilder one, the case of the woolly aphid of the apple is still further complicated by the root colonies which although hidden in their operations are really often much more pernicious than the colonies on trunk and branches. These root colonies ordinarily remain underground all the year round, apparently until the roots become too badly demolished for feeding purposes.

Economic Status.

The danger from the woolly aphid is greatest to nursery stock and young orchards. Mr. Marlatt (Journal of Economic Entomology, Vol. 4, pp. 116-117) in recording the use of American-grown apple seedlings says:—"Mr. F. W. Watson, of Topeka, Kans., in an article in the *National Nurseryman* for January, 1910, p. 437, on 'American-grown Apple Seedlings,' states that from twenty to forty million of American-grown apple seedlings are used in this country every year, the production of about a dozen nursery firms. The bulk of the seed used comes from France, and therefore is of the same stock as the imported French seedlings."

Mr. Lohrenz (1911) in recording observations on two-year-old nursery stock made at three nurseries containing respectively

*We have an exact parallel in *Pemphigus tessellata* or the woolly aphid of the alder with a cycle including a spring migration from the maple leaf to alder and a fall or return migration to the maple and also a generation of hibernating nymphs remaining under leaves about the base of the alder during the winter and ascending to the stem before feeding in the spring.

about 30,000; 45,000; and 300,000 trees, states that he found from 20 per cent to 25 per cent of the trees infested by the woolly aphid.

In circular No. 20, Bureau of Entomology U. S. Department of Agriculture (revised edition 1908) the woolly aphid of the apple is characterized as "one of the worst enemies of the apple."

Mr. Alwood (1904) of the Virginia State Crop Pest Commission in his excellent account of this insect states "On nursery stock the woolly aphis is a most serious pest, and under some circumstances it ruins a large percentage of the apple trees in the nursery."

On page 5 of Bulletin 133 of the Colorado Experiment Station the following statement is made:

"If Colorado orchardists should vote their opinion as to what ought to be called the worst orchard pest in the state, it is very doubtful whether the codling moth, or the woolly aphids, would carry off the honors."

Although it would be easy to compile testimony of this character against the woolly aphid as an enemy to young apple trees from numerous and widely separated parts of our country, they would be chiefly a repetition of what has already been said.

During those seasons when the species is abundant it is also a serious pest on American elm. Some springs in the vicinity of Orono practically every branch of many trees is tipped with an unsightly cluster of deformed leaves or "rosette" gall. Such an infestation, to say the least, mars the beauty of a large tree and is a heavy handicap for a young one.

LIFE CYCLE OF WOOLLY APHID OF APPLE.

(Exclusive of root forms.)

ELM: Primary Host.

EGGS.
(Under bark all winter)

STEM-MOTHER.
(first generation in leaf.
Apterous viviparous females).

SECOND GENERATION.
(apterous viviparous females in leaf).

SPRING MIGRANTS Migrates to apple . . . .
(third generation. Alate viviparous).

Migrate to elm . . . FALL MIGRANTS. (Alate viviparous parthenogenetic females, mature Aug.-Sept. sexuparae.)

APTEROUS OVIPAROUS FEMALES AND APTEROUS MALES.

EGGS.
(under bark all winter).

Apple: Alternate Host.

NYMPHS.
(Hibernating young migrating to trunk or branches in early spring)

SEVERAL GENERATIONS.

FOURTH GENERATION.
(apterous viviparous females).

FIFTH GENERATION.
(apterous viviparous females).

APTEROUS VIVIPAROUS PARTHENOGENETIC FEMALES, mature in Aug.-Sept.

HIBERNATING NYMPHS
(protected during winter about crown of tree).

STRUCTURE KEY.

Woolly Aphid of Apple.

A. Apterous forms. Antennæ without annulations.

B. Females.

C. Viviparous.

D. Antenna typically 5-jointed, Fig. 68. Wax glands not of type shown in Fig. 61. First spring generation hatched from over-wintering egg and found in elm rosette early in June.....*Stem Mother.*

DD. Antenna 6-jointed. Fig. 68, No. 80. Wax glands as shown in Fig. 61 and Fig. 68, No. 80. Progeny of stem mother developing in rosette in June .....*Second Elm Generation.*

DDD. Antenna 6-jointed. Fig. 68, No. 82. Wax glands of same type as those shown in Fig. 61. On apple bark or water shoots .....*Summer Generations.*

DDDD. Structure about as with summer generations On apple roots all times of year.....*Root Generations.*

DDDDD. Young born late in fall and living over winter about crown of tree, apparently without feeding until spring, when they ascend to apple bark and attain their growth .....*Hibernating Nymphs.*

CC. Oviparous.

Antenna 5-jointed, Fig. 64. Minute beakless form which deposits the over-wintering egg. Rarely seen but easily obtained by imprisoning fall migrant in vial..*True Female.*

BB. Minute beakless form smaller and more slender than true female. Antenna 5-jointed. Fig. 65. Rarely seen but easily obtained, by imprisoning fall migrant in vial.....*True Male*

AA. Alate forms. Antennæ with annulations.

B. Antenna typically with III as long as or longer than IV+V+VI. VI typically without annulations. Fig. 68, No. 81. Developing in June-July in elm rosette and migrating to apple, hawthorn and mountain ash. Progenitor of summer generations .....*Spring Migrant*

BB. Antenna much as in spring migrant, though usually shorter. VI typically with 2 or more annulations. Fig. 68, Nos. 83, 84, 85. Developing in fall in woolly colonies on bark of apple, hawthorn and mountain ash. Fig. 62. Progenitor of true males and females .....*Fall Migrant*

HABITAT KEY.

Woolly Aphids of the Elm.

A key to aid in distinguishing the woolly aphid of the apple from the other elm species with which it may easily be confused in the spring of the year.

A. Conspicuous woolly colonies on bark of *Ulmus americana.* Throughout the summer on young elms. No alternate host known. Widely distributed in America.....*S. rileyi.*

AA. Spring generations in elm leaves, causing various types of deformation.

B. Large baggy gall on *Ulmus campestris.* Alternate host unknown. European species. Taken in Connecticut in 1913 .....*S. lanuginosa.*

BB. Terminal leaf cluster or rosette (Figs. 59-60) on *Ulmus americana.* Spring migration to apple, mountain ash, and hawthorn. Maine to Colorado.....
.....*S. lanigera* (*americana* in part, of authors).

BBB. Leaf curl or roll type of deformation.

C. Leaf roll of *Ulmus scabra* and *U. campestris.* Antenna of winged generations with V and VI without annulations. Spring migration to gooseberry and currant. European species. In America found in California, Oregon and Maine (1913).....*S. ulmi* (*fodiens*).

CC. Leaf roll of *Ulmus americana.* Second apterous spring generation with wax gland distinctly unlike those of Fig. 61. Spring migrant with antenna typically with III not longer than IV+V+VI. Alternate host *Amelanchier* the roots of which are infested.* Maine to California .....*S. americana* in part, of authors.

*Bulletin 241. Maine Agricultural Experiment Station.

Preventive and Remedial Measures.

The foregoing account of the habits and characteristics of the woolly aphid will suggest certain measures to control it.

The protection of seedling apples from infestation by the woolly aphid while still in the nursery has heretofore been an exceedingly difficult matter it would seem from the amount of infested stuff that is yearly condemned. But with the knowledge that the source of danger lies in the migrants from the previously unsuspected elm leaf, it is seen to be possible to control the nursery stock by establishing nurseries at a safe distance from susceptible elm trees or clearing out the elms from the vicinity of large nurseries. As there are many places in the country where the elm is not at all abundant this would often be entirely practicable and where so would be the simplest and most effective method of protection. As it is the seedling trees that are most susceptible to injury and when attacked most seriously damaged by the woolly aphid a method of protection for the young trees while in the nursery is the most desirable.

The raising of the elms and apples in the same nursery is thus seen to be a hazardous proceeding and should be avoided.

Again young orchards of clean stock set in parts of the country where the elm is not grown should be successfully protected by excluding elms from the choice of shade trees. Indeed, the matter of alternate hosts of the aphid enemies concerned should always be borne in mind in planning the trees for an estate, and only one of the two hosts necessary for the life cycle of a migratory aphid planted, where the pest is a serious one.

It is desirable that data concerning the relative susceptibility of different varieties of apple should be accumulated with a view to using the more resistant for root stock, if otherwise practicable.

In dealing with infested apple trees the aphid masses on trunk and branch present no especial difficulty, and can be very readily exterminated by the use of any of the washes recommended for plant-lice, such as tobacco decoction, kerosene emulsion, a strong soap wash (Formulas A, B, C, D), the only care necessary being to see that the wash is put on with sufficient force and thoroughness to penetrate the covering and protecting cottony secretion. If the wash be applied warm, its penetration will be considerably increased.

An August spray to kill out colonies before the migrants fly and the hibernating young are produced is particularly desirable.

The much more important root feeders, however, are more difficult to reach and exterminate. The common recommendations are of applications of strong soap or tobacco washes to the soil about the crown, or soot, ashes, or tobacco dust buried about the roots; also similarly employed are lime and gas-lime.

Badly infested nursery stock should be destroyed, since it would be worth little even with the aphids removed.

Some nurseries are said to make a practice of "puddling" roots of infested stock, that is packing mud about the roots to conceal their condition. Before purchasing puddled nursery stock, the buyer should insist that the mud be washed off thoroughly so that the roots are exposed for inspection.

Proper cultural methods can hardly be overestimated in their value as a protection of young trees, as neglected orchards not only suffer heavily but serve as a breeding ground, dangerous to the neighboring trees.

FORMULA A—TOBACCO DECOCTION.

Tobcco stems or tobacco dust.....	2 pounds
Water	4 gallons

Put the tobacco in the water, enough to cover, which may be either cold or hot. Place over the fire and when the water has reached the boiling point, remove some of the fire and allow the water to simply *simmer* for fully one hour, when the liquid is ready to be drained off, diluted to the above proportions and applied. Boiling violently drives off the nicotine.

If whole-leaf tobacco is used, prepare as above, using one pound of tobacco to each four gallons of water.

No lime of other alkaline substance should be added to the tobacco *while cooking.* Apply at once, or within a few days after making if possible.

Certain reliable extracts such as *"Black Leaf," "Black Leaf 40,"* and *"Nikoteen"* are on the market and can be secured through local druggists. (The Black Leaf preparations are manufactured by *The Kentucky Tobacco Product Company,* Louisville, Ky., and are carried by the Collins Hardware Company, 97 Friend St., Boston, Mass. *Nikoteen* is manufactured by The Nicotine Manufacturing Company, St. Louis, Mo., and can be secured from Joseph Brick & Sons, 47-54 N. Market St., Boston, Mass.).

Directions for use come with the products. There is nothing to do in the preparation of these extracts except to stir the contents of the

can before pouring out any quantity for dilution. In most cases one gallon of the *Black Leaf* will be found sufficient for each seventy gallons of water. But if in the treatment of any louse this does not seem sufficient it may be used in preparation of one gallon to sixty or sixty-five gallons of water. Careful sprayers have usually succeeded in killing plant lice with this preparation in the proportion of one gallon to each one hundred gallons of water. Thoroughness of application is of as much importance as the strength of material used.

Nikoteen is a more concentrated abstract, 1 part being used with from 400 to 600 parts of water.

Black Leaf 40 is a concentrated solution of nicotine-sulphate and is widely and successfully used in large western orchards, at the rate of 1 part to 800 or 900 parts of water.

It is the common practice to add soap,—whale oil soap or good laundry soap at the rate of 2 bars to 50 gallons. This is to lessen the formation of drops, causing the spray to cover surfaces more in the form of thin film.

Better success is obtained by some by using a little lime instead of soap, the inert solid in suspension aiding the extract to "wet" and "stick" to the bodies of the aphids. For this purpose 1 pound of stone lime, slaked and strained into 50 gallons of tobacco extract as prepared for application, is sufficient.

Formula B.—Kerosene Emulsion.

Hard Soap	1-2 pound
Boiling Water	1 gallon
Kerosene	2 gallons

To prepare dissolve one-half pound of soap in one gallon of soft water by boiling; when well dissolved and still boiling hot, remove from the fire and add two gallons of kerosene, and agitate at once as briskly as possible. The emulsion is more readily made if the Kerosene first be heated by immersing the vessel containing it in a larger vessel of boiling water. *Never* heat the kerosene over a direct fire.

If large quantities are being made, a good way to emulsify is to use a force pump and spraying nozzle and pump the mixture as forcefully as possible back into the vessel containing it. If the emulsion is properly formed, the whole mass will appear much like whipped cream and will mix readily in water without a film of oil rising to the top.

As soon as emulsified, add twenty-seven gallons of water and use at once. This will make thirty gallons of the mixture, and such an emulsion will be one-fifteenth oil (or a 7 per cent emulsion). This is the strength ordinarily used for the destruction of insects upon plants. For larger or smaller quantities, prepare in the same proportions.

Sometimes the emulsion is not perfect and a little oil rises to the top. In such cases, if the last in the barrel or tank is pumped out upon the

foliage, it is likely to burn it. So it is advisable, unless the emulsion is of good quality, to throw out the last few gallons, making no use of it.

It is best to dilute and apply kerosene emulsion as soon as it is prepared.

Avoid using alkali or any hard water in making the emulsion, as it will cause the oil to separate and rise to the top. Any clean, soft water will usually give good results.

Formula C.—Miscible Oils.

There are several miscible oils upon the market which may be added directly to water forming a milky emulsion at once. In the preparation of any of these, such as "Scalecide," or "Target Brand Scale Destroyer" or "Killoscale," add the oil directly to the water with a little stirring. One gallon of the miscible oil in 30 to 50 gallons of water will make a mixture, which in most cases will be strong enough to kill plant lice, if thoroughly applied.

Formula D.—Whale-oil or Fish-oil Soaps.

The so-called whale-oil or fish-oil soaps which are quite extensively used for the destruction of plant lice, will usually be effective if thoroughly applied in the proportion of one-pound of the soap to each six or eight gallons of water. There are numerous brands of these soaps upon the market. Among those that have been used quite successfully are Good's Whale-Oil Soap and Bowker's Tree Soap.

* * * * * * * * *

In recent years tobacco extracts have rapidly taken the place of other remedies for aphids, and well informed apple growers are using them almost to the exclusion of other insecticides. It should be remembered that this is a contact insecticide and kills only the insects actually touched. It is, therefore, necessary to be very thorough in the spraying

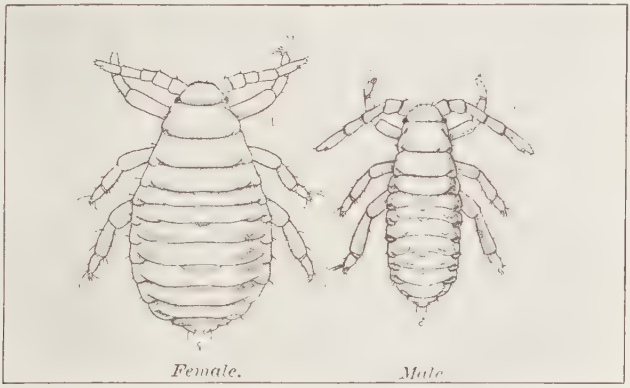
FIG. 58. Seedling mountain ash photographed June 25, 1913 to show colony of woolly aphids which are the progeny of migrants from elm leaf rosette caged with mountain ash, June 17, 1913. Two apterous generations matured on this seedling, but the third generation proved too much for the little tree which was so nearly dead by August 10 that the last of the aphid colony perished at that time.

Fig. 59. Young rosette photographed June 6, 1913. Small picture at right.

Fig. 60. Old rosette photographed July 17, 1913.

Fig. 61. Dorsal wax gland of rosette aphid, second generation. A & B, a pair on head. C & D, a pair on prothorax. Notice that the sections are not uniform in number as is often the case.

Figs. 62 and 63. Woolly Aphid. Winged and wingless forms. Greatly enlarged. (After Marlatt.)



Figs. 64 and 65. Mature sexual individuals of the Woolly Aphid,—the oviparous female and male. Real size shown in circles at right of figures. (After Alwood.)

Fig. 66. Apple root, showing knotty growth caused by Woolly Aphid.

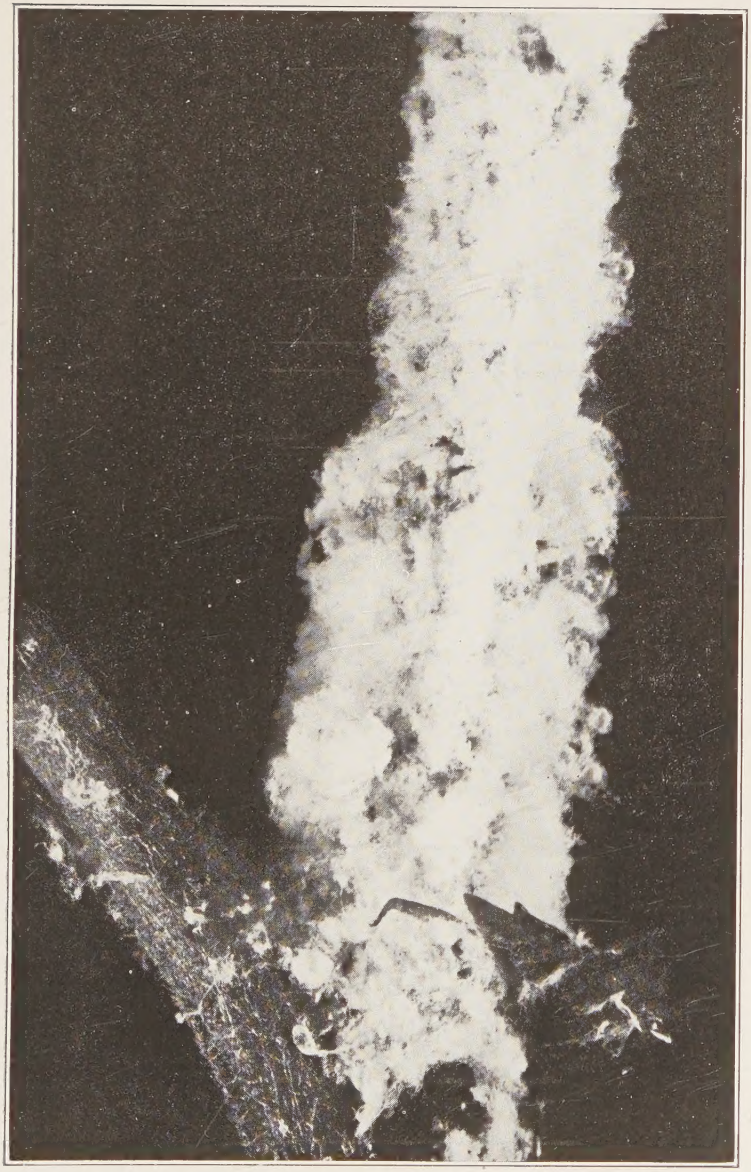


Fig. 67. Nymphs of the Woolly Aphid, *Schizoneura lanigera* on water shoot of mountain ash, *Pyrus americana*,—the immediate progeny of migrants from elm leaf rosette. Photographed at Orono, June 28, 1912. Enlarged.

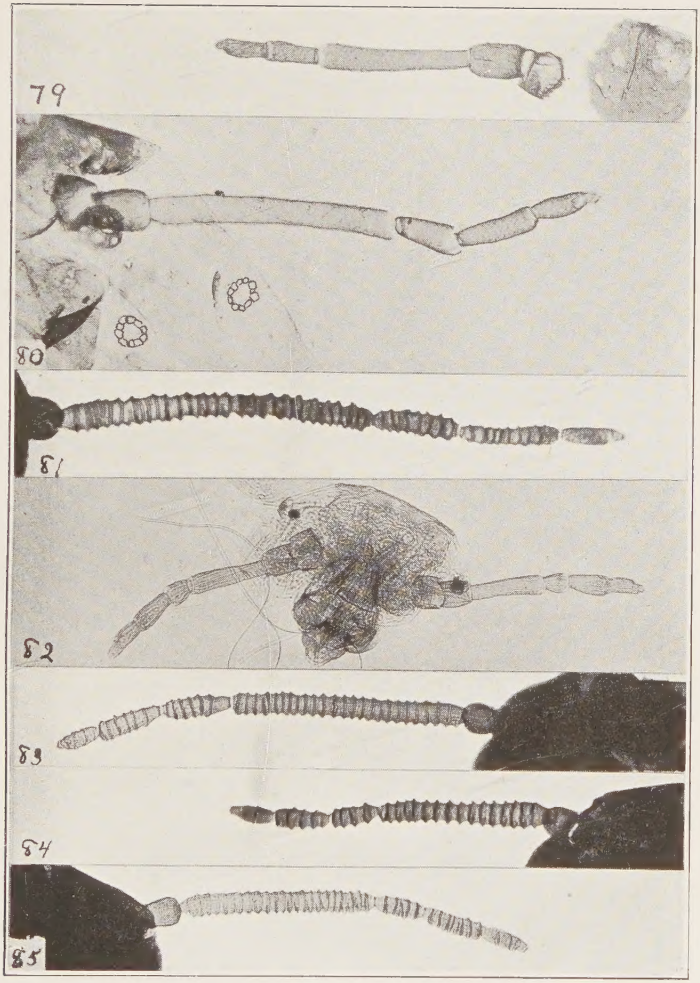


Fig. 68. Nos. 79-85. Antennæ of Woolly Aphid. No. 79—Stem mother from rosette June 5, 1913 (33-13); No. 80—Second generation from rosette June 12, 1913; No. 81—Spring migrant from rosette and progenitor of summer generations on *Pyrus* (57-13); No. 82—Apterous viviparous form on apple bark (98-08); No. 83—Fall migrant from apple (115-06; No. 84—Fall migrant from bred colony on apple; No. 85—Fall migrant from *Crataegus*.